Mr. Wood's specimen, and to which I ascribe the character of drills.[1]

Figure 3.—Original made of light-brown stone of chalcedonic appearance. Colorado. (Museum No. 9208.)

Figure 4.—Yellowish flint. Ohio. (Museum No. 16,484.)

Figure 5.—Gray jasper. New York. (Mus. No. 6180.)

Figure 6.—Cast of a large implement of brownish hornstone. The original is in possession of Mr. L. Leppelman, of Fremont, Ohio. (Museum No. 35,624.)

Figure 7.—Yellowish-brown jasper. Connecticut. (Museum No. 6084.)

Figure 8.—Dark-gray hornstone. Ohio. (Museum No. 16,484.)

Figure 9.—Light-reddish jasper. West Virginia. (Museum No. 13,376.)

Having properly hafted the original of Figure 8, I operated with it on a piece of an aboriginal potstone vessel, three-fourths of an inch in thickness, which I perforated in about twelve minutes, the result being a bore not quite as regular as that exhibited in Mr. Wood's specimen, but otherwise resembling it in all essential points. The manipulation was the same as in the previously-described experiment by which I obtained a small bi-conical perforation.

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ON THE EFFECT OF IMPACTS AND STRAINS ON THE FEET OF MAMMALIA.[2]

BY E. D. COPE.

THE principal specializations in the structure of the feet of the Mammalia may be summarized as follows:

I. The reduction of the number of the toes to one in the *Perissodactyla* (horses, etc.), and two in the *Artiodactyla* (cloven feet).

II. The second hinge-joint in the tarsus of the *Artiodactyla.*

[1] The specimen from the Yorkshire Wolds, represented by Figure 231 on page 291 of Mr. Evans's work (Ancient Stone Implements, etc.) appears to belong to the same class of tools.

[2] Read before the National Academy of Sciences, April, 1881. Abstract. Some of the points of this paper have already been discussed in the NATURALIST (April), but the present abstract contains additional matter.

III. The trochlear ridges and keels at the various movable articulations of the limbs. These are as follows:

1. Looking downwards—
   - *α.* Intertrochlear crests of the humerus.
   - *β.* On the carpal end of the radius.
   - *γ.* Metacarpals, distal ends.
   - *δ.* Tibia distally.
   - *ε.* Metatarsals distally.
2. Looking upwards—
   - *α.* Radius distally.
   - *β.* Astragalus, edges.
   - *γ.* Astragalus distally (*Artiodactyla*).
   - *δ.* Phalanges (very weak).

The following observations may be made respecting the structures included under division III: The trochlear keels which look downwards are much the most prominent and important. Those enumerated as looking upwards are weak and insignificant, or of a different character from the down-looking ones. The latter are all projections from the middles of the ends of the respective elements. The up-looking are generally projections of the edges of bones. Such are the lateral crests of the astragalus,

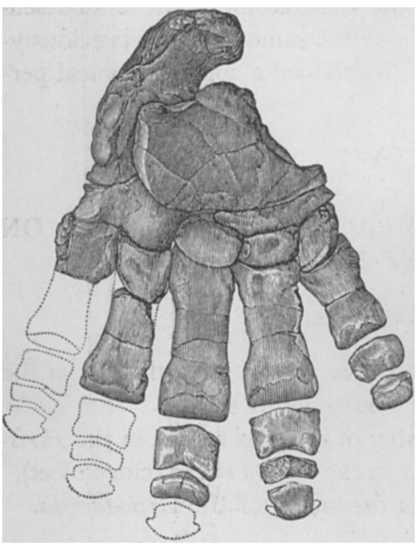

FIG. 1.

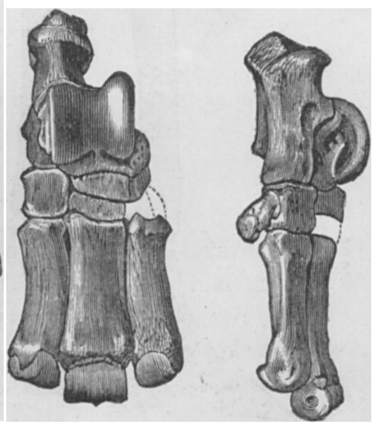

FIG. 2.

FIG. 1.—Right posterior foot of a species of *Coryphodon* from New Mexico, one-half nat. size. From Report Expl. W. of 100th Mer., G. M. Wheeler, IV, Pl. LIX.

FIG. 2.—Right posterior foot of *Aphelops megalodus* Cope, from Colorado, one-half natural size. From Report U. S. Geol. Surv. Terrs., F. V. Hayden, IV, Pl. CXXX.

and the adjacent edges of the cuboid and navicular bones which

cause the distal emargination of the astragalus in the *Artiodactyla.* The proximal ridges of the phalanges are very weak, and the concavities in the extremity of the radius cannot be called trochlear, as they are adaptations to the carpal bones.

I. The reduction in the number of toes is supposed to be due to the elongation of those which slightly exceeded the others in length, in consequence of the greater number of strains and impacts received by them in rapid progression, and the complementary loss of material available for the growth of the smaller ones. This is rendered probable from the fact that the types with reduced digits are dwellers on dry land in both orders, and those that have more numerous digits are inhabitants of swamps and mud. In geological history it is supposed that the Perissodactyles

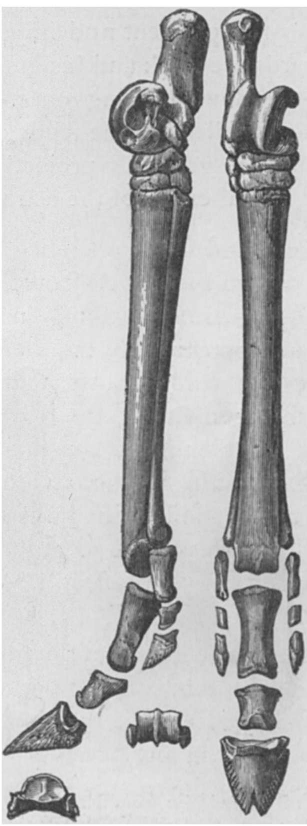

FIG. 3.

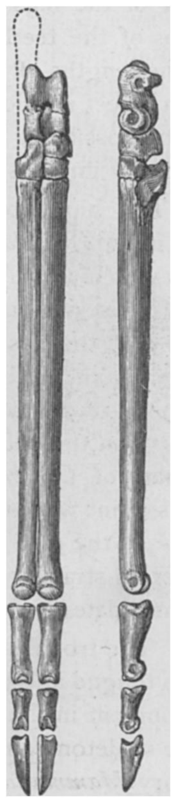

FIG. 4.

FIG. 3.—Right posterior foot of *Protohippus sejunctus* Cope from Colorado, about one-half natural size. From Report U. S. Geol. Surv. Terrs., F. V. Hayden, IV.

FIG. 4.—Right posterior foot of *Poëbrotherium labiatum* Cope, from Colorado, three-fifths nat. size. From Hayden's Report, IV, Pl. CXV.

(figures 2–3) originated from the *Amblypoda*, or primitive *Ungulata* (figure 1), which first assumed terrestrial habits, while the *Artiodactyla* (figures 4 and 9–11), originating from the same order, long continued as mud dwellers; as witness the hippopotami and hogs of to-day. The mechanical effect of walking in the mud is to spread the toes equally on opposite sides of the middle line. This would encourage the equal development of the digits on each side of the middle line, as in the cloven-footed types. In progression on hard ground, the longest toe (the third) will receive the greatest amount of shock from contact with the earth. There is every reason to believe that shocks, if not excessive, encourage growth in the direction of the force applied. This is strongly suggested by the relations between the length of the legs and the rate of speed of animals; and the lengths of the teeth and their long-continued use. Certain it is that the lengths of the bones of the feet of the Ungulate orders have a direct relation to the dryness of the ground they inhabit, and the possibility of speed which their habitat permits them, or necessarily imposes on them.

II. The hinge between the first and second series of tarsal bones in the *Artiodactyla*, may be accounted for by reference to the habits which are supposed to have caused the cloven-footed character. Observation on an animal of this order walking in mud, shows that there is a great strain anteroposteriorly transverse to the long axis of the foot, which would readily cause a gradual loosening of an articulation like that connecting the two series of tarsals in the extinct *Amblypoda*. Any one who has examined this part of *Coryphodon* will see that a little additional mobility at this point would soon resemble the second tarsal joint of the hogs. In the case of animals which progress on hard ground, no such cross-strain would be experienced, and the effect would be to consolidate by flattening the fixed articulation.

III. The trochleæ. These prominences, which form the tongues of the tongue and groove articulations, exhibit various degrees of development in the different *Mammalia*. Those of different parts of the skeleton coincide in their condition in any one type of ambulatory *Mammalia*, and so may be all considered together. This fact suggests strongly that they are all due to a common cause.

They are all imperfect in the *Rodentia* and *Carnivora* (figures 5–6) (except the *Leporidæ*, which are especially characterized by

their great speed). Among ungulates they are very imperfect in the *Proboscidea.* The orders mentioned all have elastic pads on the under sides of their feet or toes. The same is true of the lowest types of both the *Artiodactyla* and *Perissodactyla,* the hippopotami and rhinoceroses. In the *Ruminantia* the trochleæ are well developed (figure 10) with one ex-

FIG. 5. FIG. 6.

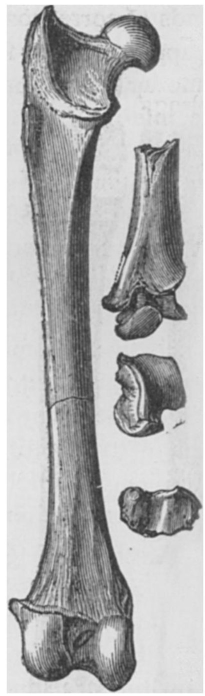

FIG. 8. FIG. 7.

FIG. 5.—Distal extremity of tibia of *Amblyctonus sinosus* Cope. FIG. 6.—Distal extremity of tibia of *Oxyæna morsitans* Cope. Both flesh-eaters and two-thirds natural size. From Report Expl. and Surv. W. of 100th Mer., G. M. Wheeler, IV, Pt. II.

FIG. 7.— End of tibia and astragalus of *Archælurus debilis.* FIG. 8.—Femur of *Nimravus gomphodus.* Carnivora, one-third natural size. Mus. Cope.

ception, and that is the distal metacarpal and metatarsal keels of the *Camelidæ* (figure 9). These animals confirm the probability of the keels being the effect of long-continued shocks, for they are the only Ruminants which have elastic pads on the inferior sides of their digits.

That these processes may be displacements due to shocks long-continued, is rendered probable by the structure of the bones themselves. (1) They project mostly in the direction of gravity. Constant jarring on the lower extremity of a hollow cylinder with soft (medullary) contents, and flexible end walls would tend to a decurvature of both inferior and superior adjacent end walls. If the side walls are wide and resistant, the projection will be median, and will be prolonged in the direction of the

flexure of the joint. (2) They fit entering grooves of the proximal ends of corresponding bones. These will be the result of the same application of force and displacement, as the protrusion of the inferior, commencing with a concavity (*Elephas*); becoming

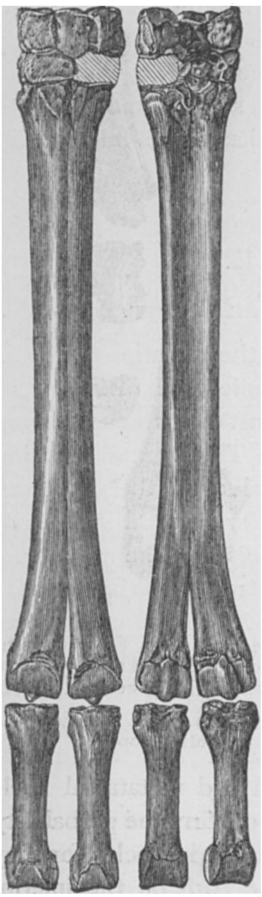

FIG. 9.

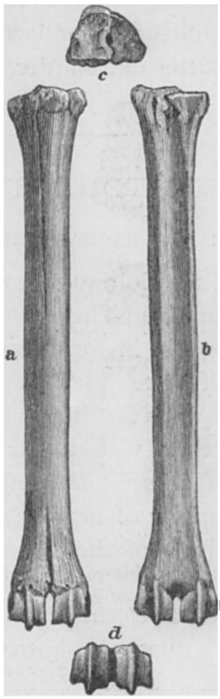

FIG. 10.

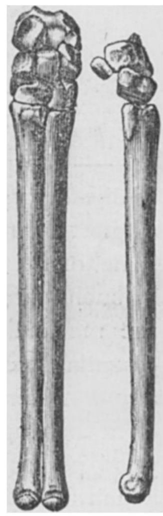

FIG 11.

FIG. 9.—Part of anterior foot of *Procamelus occidentalis* from New Mexico. From Report of Capt. G. M. Wheeler, Vol. IV, Pt. II.

FIG. 10.—Metacarpals of *Cosoryx furcatus* from Nebraska, two thirds natural size; *a*, anterior face; *b*, posterior; *c*, proximal end; *d*, distal end.

FIG. 11.—Left forefoot with part of radius of *Poëbrotherium vilsoni* Leidy, from Colorado, three-fifths natural size. From Hayden's Report, IV.

more concave (Fig. 7), and becoming finally a groove. (3) When the dense edge of a bone, as in the case of the lateral walls of the astragalus, is presented upwards, a groove is produced in the

down-looking bone; *e. g.*, the lateral grooves of the distal end of the tibia. (4) When the inferior bones are the denser, the superior articular face yields; *e. g.*, the distal end of the radius to the first row of carpals (Fig. 11).

(5) The metapodial keels commence in the lower types on the posterior side of the distal extremity of the bone. This is partly due to the presence there of a pair of sesamoid bones, which with the tendons in which they are developed, sustain and press on the lateral parts of the extremities, and leave the middle line without support.

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EDITORS' TABLE.

EDITORS: A. S. PACKARD, JR., AND E. D. COPE.

—— Morphological biology treats of the relations of solid bodies of organic origin. These solid bodies are often in the highest degree irregular in form, as for instance, the squamosal bone, or the liver, of vertebrated animals. The mental handling of such material requires faculties which belong to the artist and the mechanic, together with a capacity for generalization not essential to either of those classes of specialists. The mastery of any considerable number of organic forms requires the exercise of a thorough analysis of them, which of course presupposes good perceptive faculties. The latter form the important class which furnishes material to the reflective department of the mind, and without which the grandest powers of thought wander aimlessly in the search of truth, for want of fundamental facts.

While a definite idea of the forms of organic bodies is necessary to the biological thinker, the power of describing them is necessary to the biological writer. It is absolutely essential that the describer of structure and form shall use language which is not susceptible of several meanings, and that he shall know how to express contrasts when describing different objects. It is not uncommon to find divisions or groups of various grades defined in somewhat the following manner: Div. I. Legs long; bill curved; Div. II. Tail truncate; legs scaly. On reading this, the inexperienced student is impressed with the occult wisdom of the oracle, while the scientist, on the other hand, feels his fulminate one degree denser than before. Our experience leads us to sug-